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Montana Department of Fish, Wildlife & Parks

MIDDLE CLARK FORK RIVER FISHERY MONITORING STUDY:

Evaluation of the Effects of Pulp and Paper Mill Effluents on the Fish Population

by

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ABSTRACT

A fishery study was initiated on September 1, 1984, in a 192.1 - kilometer reach of the main stem of the Clark Fork River from Milltown Dam to the confluence of the Flathead River. The study was designed to evaluate potential effects of pulp mill effluents on the sport fishery by monitoring trout reproductive success and trout population characteristics in study areas located upstream and downstream from the pulp mill effluent discharge. The bulk of the sport fishery in the middle Clark Fork River is provided by rainbow trout along with a few westslope cutthroat, brown and bull trout.

Brown trout egg mortality rates during the 1984-85 incubation period were nearly 100% greater at the Champion and Cyr bioassay sites, downstream from the pulp mill effluent discharge, than at Council Grove, the upstream control. Also, brown trout embryo development was significantly slower at the Champion and Cyr sites than at Council Grove. High brown trout egg mortality and retarded embryo development were associated with low intergravel dissolved oxygen concentrations found at the bioassay sites located downstream from the pulp mill effluent discharge.

The EPA criterion for intergravel dissolved oxygen concentration was violated at four of six, or 67 percent, of the monitoring sites located downstream from the pulp mill effluent discharge during the 1985-86 brown trout egg incubation period. Elevated concentrations of sulfate, sodium and chloride ions in intergravel water samples collected downstream from the pulp mill suggest that the mill's effluent discharge affects intergravel water quality as far downstream as the Superior monitoring station, 51.8 miles below the mill. Chronic and acute toxicity criteria for phthalate esters were exceeded at Champion and chronic toxicity criteria were exceeded at Cyr in intergravel water samples collected during the 1985-86 brown trout egg incubation period.

Estimates in four study sections indicated the middle Clark Fork River supports from 175 to 402 catchable rainbow trout per mile, and rainbow trout comprised more than 90 percent of the catchable trout population. This density of catchable trout is less than expected for comparable trout streams the size of the Clark Fork. While the Clark Fork River supports an average of two to four hundred catchable trout per mile, other large trout rivers in Montana often support two to three thousand or more catchable trout per mile.

Preliminary findings indicate growth rates of trout in the Clark Fork are relatively high when compared to trout streams of similar size. This indicates that food supply is probably not a limiting factor for trout populations in the Clark Fork River. A saturation plant of 10,000 young-of-the-year brown trout was made in the Huson section on June 23, 1986, to evaluate the possibility that recruitment is a limiting factor for trout populations in the Clark Fork River. Additional time is needed to adequately assess potential impacts of year round discharge of pulp mill effluents on trout populations and the sport fishery.

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BACKGROUND

In July of 1983 Champion International Corporation applied to the Water Quality Bureau of the Montana Department of Health and Environmental Sciences for a modification of their waste water discharge permit for the Clark Fork River. If granted, the modified discharge permit would allow Champion to release pulp mill effluents into the Clark Fork River on a year-round basis. Under its existing permit the mill was limited to discharging pulp mill effluents only during spring high water. The permit modification was requested because Champion indicated its rapid infiltration system, a collection of gravel ponds to treat effluents, was becoming clogged to the extent that treated effluents would have to be released year-round.

After a preliminary environmental review, the Water Quality Bureau issued a temporary permit on April 10, 1984, which allowed Champion to release treated pulp mill effluents into the Clark Fork River on a year-round basis for two years. This led to an intense debate over existing and future impacts of pulp mill effluents on the river. Trout Unlimited and other environmental groups demanded an Environmental Impact Statement be completed before issuance of a permanent modified permit in two years. This was followed by numerous negotiations between Champion and the groups in an attempt to work out an agreement that would be acceptable to all sides and keep the issue out of court.

By the end of March 1984 a final agreement was reached that embodied the following points:

1. The State of Montana would prepare an Environmental Impact Statement at a cost of $200,000 before issuing a permanent modified discharge permit.

2. The Montana Department of Health and Environmental Sciences would monitor water quality from Turah to the Idaho line and attempt to identify all major sources of pollution and evaluate effects of pulp mill effluents on the water quality of the Clark Fork River. In conjunction Idaho agencies would test for impacts on the river in Idaho, including Lake Pend Oreille.

3. The Montana Department of Fish, Wildlife and Parks would undertake a two year $100,000 study financed by Champion to evaluate effects of pulp mill effluents on the Clark Fork River fishery.

4. Champion agreed to sponsor an alternative methods study to consider technologies that would reduce or permanently eliminate discharges of pulp mill effluents into the river.

5. A twelve member technical advisory committee would meet on a regular basis to oversee the process. The committee included the broad based representation of Trout Unlimited, the Idaho Wildlife Federation, the Montana Evnironmental Information Center, the Green Monarch Coalition, Missoula/Mineral/Sanders County Commissioners Association, the Missoula

County Health Department, the Water Quality Bureau, Fish, Wildlife and Parks, and Champion International Corporation.

Although the agreement did not represent a final solution, a thorough two-year study would begin to provide information needed to evaluate influences of the Champion Mill on the Clark Fork River.

SCOPE OF THE FISHERY MONITORING STUDY

To evaluate a river's ability to safely assimilate additional quantities of pulp mill wastes, the current status of sport fish populations must be determined. Although fifteen species of fish are found in the middle Clark Fork River, the bulk of the sport fishery is provided by rainbow trout along with a few cutthroat, brown and bull trout (Table 1). The study evaluated potential effects of pulp mill effluents on the sport fishery by monitoring t reproductive success and trout population characteristics in areas upstream and downstream from the pulp mill effluent. The study was initiated on September 1, 1984.

There were several problems in designing this study to evaluate potentia effects of pulp mill effluents on the sport fishery. First the study was intended to document an impact from year-round discharge of effluent from Champion's mill after the discharges had already begun. Second, there was very little baseline information on the condition of fish populations in areas downstream from the Champion discharge prior to the year-round discharge situation which now occurrs. Third, the time frame for the study to assess impacts of the discharge was limited to two field seasons. This time frame was too short to provide an adequate assessment. Fourth, there are many other water quality problems in addition to pulp mill effluents which may affect the Clark Fork River fishery. Additional water quality factors which may be influencing the fishery include the Missoula sewage treatment plant effluents, potentially toxic heavy metals originating from mine tailings in the upper Clark Fork drainage and fine sediments originating from various human related activities which could impair trout food production or trout reproductive success.

The Department of Fish, Wildlife and Parks believes there is a need for a comprehensive evaluation of the Clark Fork River system which cannot be accomplished within the scope of ongoing studies. The comprehensive study should include quantification of instream flow requirements for sport fish in the main river as well as major tributaries, expand sampling to below the confluence of the Flathead River, assess seasonal and temporal distribution and movements of sport fish during both juvenile and adult life stages and identify interactions between fish populations and water quality relative to the influence of tributary streams.

Table 1. Fish species found in the Clark Fork River in Montana between Milltown Dam and the confluence of the Flathead River.

SALMONIDAE (Trout Family)	
Prosopium williamsoni - Mountain whitefish	A[1/]
Salmo clarki lewisi - Westslope cutthroat trout	R*
Salmo gairdneri - Rainbow trout	C
Salmo trutta - Brown trout	R*
Salvelinus fontinalis - Brook trout	R*
Salvelinus confluentus - Bull trout	R
ESOCIDAE (Pike Family)	
Esox lucius - Northern pike	R
CYPRINIDAE (Minnow Family)	
Mylocheilus caurinus - Peamouth	R
Ptychocheilus oregonensis - Squawfish	A
Rhinichthys cataractae - Longnose dace	C
Richardsonius balteatus - Redside shiner	A
CATOSTOMIDAE (Sucker Family)	
Catostomus catostomus - Longnose sucker	R
Catostomus macrocheilus - Largescale sucker	A
CENTRARCHIDAE (Sunfish Family)	
Micropterus salmoides - Largemouth bass	R
COTTIDAE (Sculpin Family)	
Cottus cognatus - Slimy sculpin	C

1/ Relative Abundance - A = Abundant, C = Common, R = Rare.
* Common in some tributaries of the Clark Fork in the study area.

DESCRIPTION OF AREA

This study area lies in west central Montana and includes a 192.1 - kilometer (km) (119.4 - mile) reach of the main stem of the Clark Fork River from Milltown Dam to the confluence of the Flathead River. Four fish population study sections, Milltown Dam, Missoula, Huson and Superior were established in this reach (Figure 1).

The Clark Fork River forms at the confluence of Silver Bow and Warm Springs creeks near Anaconda, Montana, and flows northwestward approximately 560 km (350 river miles) to Lake Pend Oreille in northern Idaho. The 192 km reach of the Clark Fork covered by this study is entirely free-flowing. The drainage area in this reach is mountainous and is covered with large forested tracts, the continuity of which is broken by grazing and cropland areas which are situated in valleys at lower elevations.

The Clark Fork Basin has been widely known for its mining and smelting industries. The copper mines at Butte and smelters at Anaconda, located in the headwaters of this drainage, are internationally famous. The smelters at Anaconda are presently shut down, while mining operations at Butte were resumed in July, 1986, after being shut down for several years. Logging, lumbering and paper manufacturing industries are supported by forests of the basin. Tourist trade is a large contributor to the economy. The basin is nationally known for its scenic beauty, fishing, hunting and other recreational features. Agriculture is also an important industry in the basin.

Four hydropower dams are located on the main stem of the Clark Fork River upstream from Lake Pend Oreille. Milltown Dam, the upstream boundary of the present study area, is located 362 km upstream from Lake Pend Oreille. Thompson Falls, Noxon Rapids and Cabinet Gorge dams are situated on the lower Clark Fork River 113,50 and 18 km upstream from Lake Pend Oreille. Thompson Falls Dam is located 57 km downstream from the lower boundary of the present study area. The four main stem dams contain little storage capacity and have little influence on seasonal discharge patterns.

TROUT REPRODUCTIVE SUCCESS

Bioassay of Brown Trout Egg and Sac Fry Survival

A field bioassay was conducted to evaluate potential effects of pulp mill effluents on brown trout egg and sac fry survival rates in the Clark Fork River. Egg and fry survival were monitored for brown trout, a fall spawner, because their incubation period, extending from early fall through late spring, is considerably longer than the incubation periods of westslope cutthroat and rainbow trout, the other principal trout species in the middle

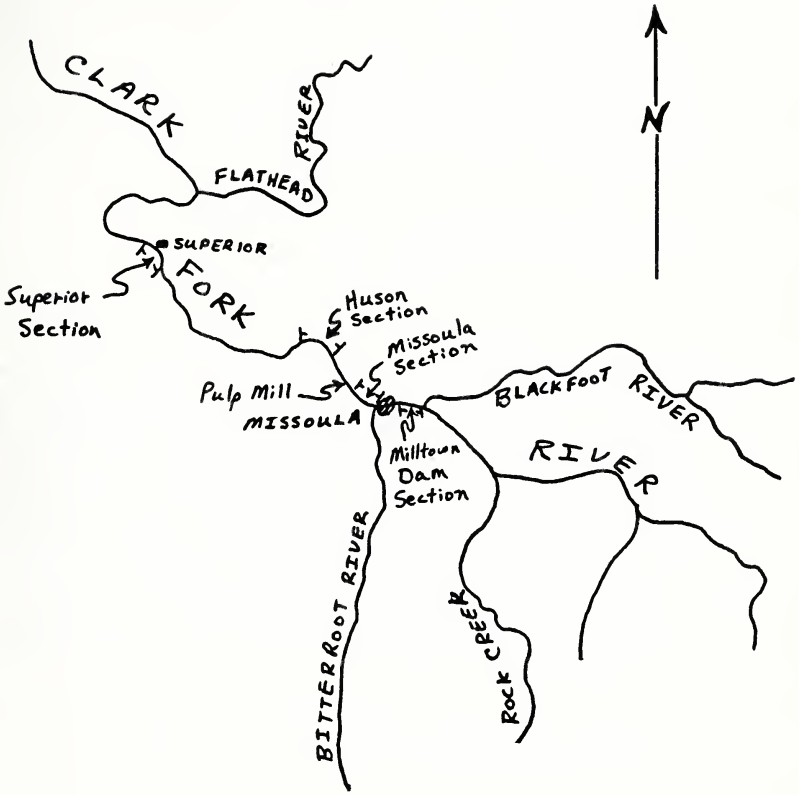

Figure 1. Map of Clark Fork River showing location of study sections.

Clark Fork River. The brown trout egg bioassay was conducted from early fall through spring, 1984-85.

Trout spawn in relatively shallow gravelly areas of the river with moderate current velocity. After a depression is dug in the spawning gravel by a female, eggs deposited in the depression by the female are fertilized by an accompanying male and covered over with four to eight inches of spawning gravel. Since intergravel water quality can influence trout egg and fry survival rates, intergravel water quality was monitored at the egg bioassay sites during the brown trout egg incubation period in 1984-85. Intergravel water quality was monitored at the egg bioassay sites and several additional sites during the brown trout incubation period in 1985-86.

1984-85 Brown Trout Egg Incubation Period

Study Sites

Three locations in the Clark Fork River were chosen for brown trout egg bioassay sites (Table 2). Site 1 was located in a side channel downstream of Council Grove near river mile 343.5. This location served as a control since it is upstream of the Champion outfall but downstream of other point sources of pollution. Site 2 was situated immediately downstream of Champion International's diffuser, which is approximately 4.9 river miles downstream from Site 1. It incorporated two exposure regimes since eggs were placed in both the main river channel, where the pulp mill effluent concentration is primarily regulated by direct surface discharge, and in a side channel adjacent to Champion's settling ponds. The two major factors affecting effluent concentrations in the side channel were uncontrolled groundwater seepage from the settling ponds and direct surface discharge. The third site was established below the pulp mill effluent mixing zone about 25.6 river miles below Site 2, just upstream from the Cyr bridge.

Table 2. Study site names, river mileage locations and legal descriptions of brown trout bioassay sites.

Site No.	Site Name	Approximate River Mile	Legal Description
1	Council Grove	343.5	T13N,R20W,S06DCC
2	Champion	338.6	T14N,R21W,S14BBB
3	Cyr	313.0	T14N,R23W,S06BCC

Methods

Ten female brown trout were collected from the Missouri River below Hauser Dam to provide eggs for use at the bioassay sites. Male brown trout from the Missouri River and Mill and Ninemile Creeks were used to fertilize the eggs. Hatchery personnel from the Jocko River State Fish Hatchery supervised the egg take. The male/female sex ratio was about 1:3. A greater number of females were spawned than necessary and roughly equal proportions of eggs from each female were used at each bioassay site to minimize any potential parental effects on survival of the eggs. Each group of eggs were water hardened using water obtained from standpipes at the respective bioassay site. After the eggs were water hardened, a portion of them were transported to Washoe Park State Fish Hatchery. These eggs were allowed to develop to the eyed stage before being planted in the Clark Fork. The other subset of eggs were immediately planted in the river at the green stage. The number of green and eyed eggs planted in the river, except for eyed eggs placed in emergence traps, was measured using a Von Bayer trough (Leitritz 1969).

Two methods were employed to assess egg survival and fry emergence at each study area. The first method involved eggs placed in fiberglass bags which were buried in the substrate. Periodically a subsample of bags was removed to monitor development and mortality. Ten groups of green eggs, which consisted of three bags each, were placed in the river at each site on November 8, 1984. Eight groups of eyed eggs, which were also composed of three bags each, were planted at each study area on December 11-12, 1984. Each of these bags contained one Von Bayer trough of eggs or 52-56 eggs (Table 3). The second method utilized fry emergence traps. This method didn't allow frequent sampling of eggs during incubation, but it provided a measure of the cumulative effects of pulp mill effluents on a group of eggs from the green or eyed egg stage through emergence of fry from the gravel. The fry emergence traps were equipped with fiberglass screen "baskets" which formed an enclosure within the substrate (Fraley et al. 1984). The baskets prevented escape of fry from the trap by lateral movement through the gravel. The emergence trap was square and covered approximately 1355 cm^2 of stream bed. The trap frame was made of strapping iron. A cross member made from plumbers tape supported 1.6 mm delta nylon netting which formed an enclosure above the substrate. A netting sock trailing behind the trap contained a collecting bottle which provided a low velocity holding area to prevent fry mortality. Three fry emergence traps containing green eggs were installed at each bioassay site on November 8, 1984. Eggs from three Von Bayer troughs were placed in each of these traps. Two emergence traps which contained eyed eggs were installed at Sites 1 and 2, and one was installed at Site 3 on December 12-13, 1984. A total of 150 eggs were placed in each eyed egg trap at Sites 1 and 2, and 149 eggs were added to the eyed egg trap at Site 3.

Table 3. The mean number and range of green and eyed eggs per Von Bayer trough at each study site during fall 1984. Standard deviations are in parentheses.

Study Site	Green Eggs			Eyed Eggs		
	Mean No. Eggs/trough	N	Range	Mean No. Eggs/trough	N	Range
1	53.5(±1.3)	10	52-55	54.6(±1.1)	10	53-56
2	54.1(±1.1)	10	52-56	54.3(±0.8)	10	53-56
3	53.5	10	-	53.5(±0.5)	10	53-54

Groundwater flow through the substrate, or apparent velocity, was measured directly with a seepage meter (Lee 1977, Lee and Cherry 1979) rather than with a standpipe (Pollard 1955, Terhune 1958). Previous standpipe methods used to determine apparent velocity were based on an erroneous premise that the direction of groundwater flow in the intergravel environment is always parallel to the stream bottom when actually it is often vertical or semi-vertical (Dr. Bill Woessner, University of Montana, personal communication).

Permeability of the gravel bed at each bioassay site was calculated bimonthly during the incubation period using Mark VI standpipes as described by Terhune (1958). Three standpipes were positioned adjacent to the sites from which egg bags had recently been removed. All permeabilities were converted to a standard temperature (10°C) to facilitate comparisons of measurements.

Streambed composition at each bioassay site was determined by obtaining samples with a hollow core McNeil sampler (McNeil and Ahnell 1964). The core tube was inserted 22 cm into the streambottom. Substrate within the core was extracted and placed in the catch basin. Water depth within the sampler was measured to the nearest 0.5 cm and recorded. A one liter bottle was filled with sediment-laden water from the corer. The substrate was then removed from the catch basin and placed in a sample bag. Three substrate samples were taken adjacent to both the green and eyed egg bags at each site shortly after implantation of the bags. Additionally, one substrate sample was collected bimonthly in conjunction with the harvest of egg bags.

In the laboratory, samples were dried, sieved and weighed. Samples were sieved for a total of four minutes using a Tyler Ro-Tap shaker with ten sieves, whose mesh sizes ranged from 25.0 mm to 0.053 mm. The volume of water present in the corer was determined using the regression equation:

For water depths up to 40.0 cm

$v = 0.241d + -0.001$ $\quad r^2 = 0.99$

For water depths 40.1 to 76.5 cm

$v = 1.26d + -34.42$ $\quad r^2 = 0.99$

Where: d = water depth in cm
v = volume in liters

The water sample from the McNeil corer was transfered to an Imhoff cone and allowed to settle for a minimum of 25 minutes. The amount of settled material in the Imhoff cone and the total volume of water in the corer were used to determine the volume of sediment that remained suspended. This value was then converted to the dry weight of material in suspension. The percentages of the total sample weight in each size class and of substrate smaller than a given size were computed to determine if the amount of fines present at each site was a major factor affecting embryo survival.

Water depths, mean velocities and point velocities were measured at three locations (the upper edge, middle and lower edge) at the egg bag sites and adjacent to each emergent trap. Depths were measured to the nearest 0.05 feet. Mean velocities were measured at 0.6 of the total depth for water 2.5 feet deep or less while at greater depths measurements were obtained at 0.2 and 0.8 of the total depth and averaged. Point velocities were measured at the substrate surface.

Water quality in the intergravel environment was monitored at approximately one month intervals from November 11, 1984 to April 2, 1985, at each study site. Parameters measured included pH, alkalinity, hardness, dissolved oxygen, total and volatile suspended solids and ammonia as well as the total recoverable concentrations of copper, cadmium, zinc and iron. In addition, major cation/anion concentrations, including sulfate, chloride, sodium, potassium, calcium, magnesium, nitrate, phosphate and total dissolved solids were monitored during the final two monthly sampling periods. Water analyses were performed by the Montana Department of Health and Environmental Sciences laboratory in Helena or the Chemistry Department of the University of Montana, except for measurements of dissolved oxygen, which were determined in the field using the azide modification of the Winkler method. The intensity of heavy metal sampling was reduced after it was determined that heavy metals were not present in high enough concentrations to cause significant mortality at any of the study sites.

Initially, all intergravel water quality samples were obtained using a metal Mark VI standpipe (Terhune 1958) and a hand operated rotary pump. A hammer and driving rod were used to drive the standpipe vertically into the streambed. The two-inch perforated zone of the standpipe was driven to a depth of six to eight inches below the streambed, the approximate depth of incubating brown trout eggs. Once the standpipe was set, the loose cobble around the pipe was removed using care not to disturb imbedded bottom materials. A shovel full of sand was then applied

to the area around the standpipe before sliding the disk down the pipe and pressing it firmly to the stream bottom. More gravel and sand was added to the top of the disk. The disk prevented water from slipping down the outside wall of the standpipe which would introduce surface water to the sample. Approximately one or two liters of water was then pumped from the bottom of the standpipe to eliminate surface water and sediment which entered the standpipe during the driving process. After waiting five to ten minutes to allow the standpipe to further "seal", a tube attached to the hand pump was inserted into the pipe to approximately two inches below the water's surface and pumping was initiated.

Preliminary results showed distilled water pumped through standpipes contained background concentrations of heavy metals which were high enough to prevent accurate measurements of the water samples. PVC standpipes were then installed at each study site. A proper seal of the substrate surrounding these standpipes was not obtained so their use was discontinued. Seepage meters constructed of PVC and partially buried in the substrate were then used to collect water samples, but the slow rate of inflow combined with icing and initial flushing problems minimized their usefulness. Uncontaminated water samples for heavy metals analyses were finally obtained from a modified PVC seepage meter completely buried in the substrate. Water samples for all other parameters were obtained from the Mark VI standpipes.

A comparison of dissolved oxygen levels in water from grab samples and those obtained from the same source with the hand held rotary pump indicated that no introduction of error occurred when caution was used to avoid the addition of air bubbles (Table 4). A dissolved oxygen meter also tested failed to provide reliable results over a sustained period of time, and its use was discontinued.

Table 4. Comparison of dissolved oxygen concentrations (mg/l) from two collection methods.

Replicate	Grab Sample	Pumped Sample
A	12.6	12.5
B	12.7	12.5

Results

Depths and mean velocities at each site (Table 5) were measured shortly after implantation of the green eggs in November. They were near optimal hydraulic conditions for both brown trout spawning and egg incubation when compared to probability of use curves (Figures 2 and 3) developed by Bovee (1978). All depths and mean velocities were within Bovee's criteria curves, but velocities at Site 2 were usually lower than at the other sites. However, flow conditions at Site 2 were not "stagnant" enough to cause high embryo mortality (Reiser and White 1981). Water depth and velocity remained within acceptable criteria for brown trout egg survival at both green and eyed egg bioassay sites during the entire 1984-85 incubation period. (Figure 3 and Table 5).

Measurements of apparent velocity in the intergravel environment were very limited. However, apparent velocities monitored at each bioassay site from late February through early March indicated intergravel apparent velocity was highest at Cyr, lowest at Champion and intermediate at Council Grove (Table 6). Considerable difficulty was encountered in developing reliable techniques for measuring apparent velocity in the intergravel environment of the middle Clark Fork River. This accounts for the limited number of measurements made during the brown trout incubation period in 1984-85. Field experiments indicated standard standpipe methods developed by Pollard (1955) and Terhune (1958) for measuring apparent velocity were unsuitable for use in the Clark Fork because groundwater does not flow parallel to surface water. This violates a basic assumption for standpipe methods that groundwater does flow parallel to surface water. To replace standpipes, a variety of sizes and types of seepage meters were constructed and tested to measure apparent velocity. The limited findings in Table 6 are based on measurements of apparent velocity from these seepage meters. If other factors remain constant, higher apparent velocity should enhance egg survival by increasing the rate of oxygen supply to incubating eggs.

Measurements of intergravel permeability were consistently higher at the Champion and Cyr sites than at the Council Grove site for both the green and eyed egg bioassays (Table 7). If other factors remain constant, higher permeability should enhance egg survival by increasing the rate of oxygen supply to incubating eggs.

Brown trout egg survival rates were lower at the Champion and Cyr bioassay sites, downstream from the pulp mill effluent, than at Council Grove, the upstream control (Table 8). Since the green egg bioassay was terminated in early February due to egg freeze-up at the Champion and Cyr sites, the eyed egg bioassay provided the only valid long-term comparison of survival rates between study sites. Cumulative survival rates by early April for the eyed egg bioassay were 75.5 and 74.8 percent at Champion and Cyr compared to 87.8 percent at Council Grove (Table 9). These findings indicate cumulative egg mortality rates at Champion and Cyr were nearly 100% greater than at Council Grove.

Table 5. Physical habitat parameters of brown trout egg bioassay sites in the Clark Fork River during the 1984-85 incubation period. Standa deviations are in parentheses.

Date	Site	Egg Type	Depth (ft) N	Depth (ft) $\bar{x}$	Mean Velocity (ft/sec) N	Mean Velocity (ft/sec) $\bar{x}$	Point Velocity (ft/sec) N	Point Velocity (ft/sec) $\bar{x}$
11/15-16/84	1	Green	6	0.94(±0.19)	6	2.09(±0.60)	6	1.09(±0.41)
"	2	Green	6	0.96(±0.05)	6	2.41(±0.11)	6	1.08(±0.42)
"	3	Green	6	1.00(±0.17)	6	1.98(±0.51)	6	1.17(±0.44)
12/8/84	1	Green	1	0.7	1	1.15	1	0.45
"	2	Green	1	0.55	1	0.1	1	0.0
"	3	Green	1	0.75	1	0.75	1	0.25
1/15-17/85	1	Green	6	0.77(±0.30)	6	1.22(±0.64)	6	0.50(±0.40)
"	2	Green	6	0.47(±0.13)	6	0.50(±0.08)	6	0.23(±0.11)
"	3	Green	6	0.28(±0.14)	6	0.09(±0.15)	-	
"	1	Eyed	5	1.29(±0.12)	5	2.28(±0.37)	5	0.78(±0.39)
"	2	Eyed	5	1.24(±0.29)	5	1.75(±0.37)	5	0.63(±0.24)
"	3	Eyed	4	0.66(±0.14)	4	2.15(±0.27)	-	
1/22-24/85	1	Green	6	0.68(±0.30)	6	1.17(±0.90)	6	0.54(±0.46)
"	2	Green	6	0.37(±0.10)	6	0.25(±0.08)	6	0.06(±0.08)
"	3	Green	6	0.99(±0.27)	6	1.88(±0.30)	6	0.76(±0.25)
"	1	Eyed	5	1.17(±0.06)	5	2.29(±0.35)	5	1.20(±0.39)
"	2	Eyed	5	1.11(±0.19)	5	1.56(±0.24)	5	0.70(±0.27)
"	3	Eyed	4	1.38(±0.38)	4	3.09(±0.71)	4	1.38(±0.31)
2/22-25/85	1	Green	6	0.72(±0.29)	6	1.14(±0.76)	6	0.37(±0.32)
"	2	Green	6	0.41(±0.13)	6	0.49(±0.16)	6	0.28(±0.20)
"	3	Green	6	0.95(±0.25)	6	1.73(±0.30)	6	0.73(±0.41)
"	1	Eyed	5	1.22(±0.10)	5	2.42(±0.29)	5	0.84(±0.18)
"	2	Eyed	5	1.21(±0.29)	5	1.77(±0.23)	5	0.78(±0.28)
"	3	Eyed	4	1.13(±0.05)	4	3.08(±0.71)	4	0.83(±0.38)
3/14-15/85	1	Green	6	0.72(±0.26)	6	1.49(±0.66)	6	0.75(±0.30)
"	2	Green	6	0.55(±0.09)	6	0.79(±0.23)	6	0.32(±0.20)
"	3	Green	6	0.90(±0.25)	6	1.79(±0.29)	6	0.73(±0.26)
"	1	Eyed	5	1.27(±0.10)	5	2.66(±0.30)	5	1.09(±0.33)
"	2	Eyed	5	1.42(±0.31)	5	1.78(±0.26)	5	0.69(±0.15)
"	3	Eyed	4	1.08(±0.10)	4	2.96(±0.57)	4	1.08(±0.10)
3/27,29 & 4/3/85	1	Green	6	0.73(±0.30)	6	1.83(±0.82)	6	1.00(±0.32)
	2	Green	6	0.70(±0.08)	6	1.38(±0.12)	6	0.63(±0.15)
"	3	Green	6	1.62(±0.19)	6	2.44(±0.19)	6	0.90(±0.33)
"	1	Eyed	5	1.29(±0.18)	5	2.47(±0.29)	5	1.42(±0.15)
"	2	Eyed	5	1.56(±0.30)	5	1.94(±0.19)	5	0.74(±0.20)
"	3	Eyed	4	2.11(±0.10)	4	2.74(±0.33)	4	0.75(±0.27)

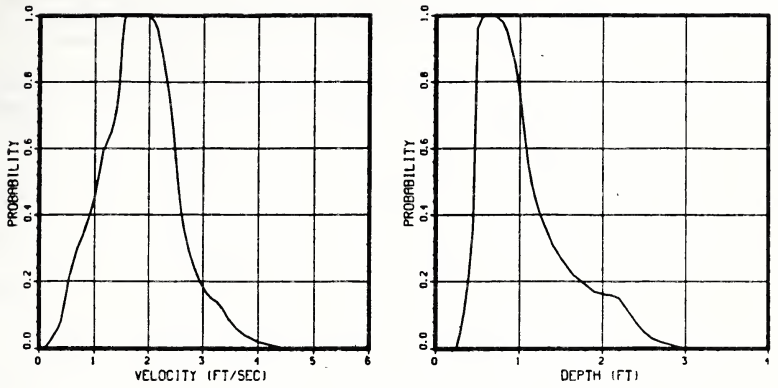

Figure 2. Probability of use criteria curves for brown trout spawning (from Bovee 1978).

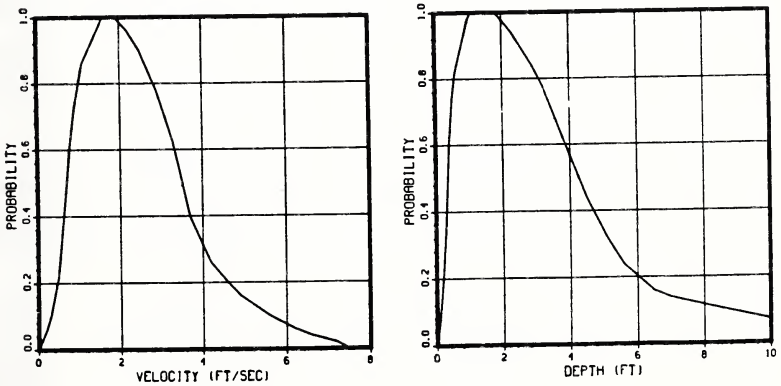

Figure 3. Probability of use criteria curves for brown trout egg incubation (from Bovee 1978).

Table 6. Groundwater flow into the Clark Fork River during the 1984-85 incubation period measured by seepage meters at brown trout egg bioassay sites. Standard deviations are in parentheses.

Site	Date	No. of measurements	Apparent velocity $ml/m^2 . min$	Apparent ve cm/hr
2	12/19/84-1/4/85	3	0.70 (±0.69)	0.25 (±0.25
1	2/22-3/5/85	2	0.34 (±0.15)	0.12 (±0.06
2	2/21-3/5/85	2	0.14 (±0.04)	0.05 (±0.01
3	2/25-3/5/85	2	0.80 (±0.04)	0.29 (±0.01
2	3/6-3/22/85	2	1.02 (±0.37)	0.37 (±0.13
2	3/27-4/2/85	3	-	3.71 (±2.80

Table 7. Permeabilities at 10 C from the brown trout bioassay sites in the Clark Fork River during the 1984-85 incubation period. Standard deviations are in parentheses.

Date	Site	Egg Type	Number (N)	Permeability K_{10} (cm/min)	Permeabili K_{10} (cm/hr
11/19-20/84	1	Green	6	0.9 (±0.6)	54 (±36)
"	2	Green	6	5.0 (±2.4)	300 (±144
"	3	Green	6	2.6 (±2.6)	156 (±156
1/22-25/85	1	Green	6	3.4 (±0.8)	204 (±48)
"	2	Green	6	7.5 (±5.2)	450 (±312
"	3	Green	6	10.1 (±1.4)	606 (±84)
"	1	Eyed	6	3.9 (±1.9)	234 (±114
"	2	Eyed	6	8.3 (±4.0)	498 (±240
"	3	Eyed	6	24.6 (±9.2)	1476 (±552
3/28-29 & 4/3/85	1	Green	6	3.0 (±1.9)	180 (±114
"	2	Green	6	6.0 (±4.4)	360 (±264
"	3	Green	6	5.3 (±2.8)	318 (±168
"	1	Eyed	6	4.4 (±2.3)	264 (±138
"	2	Eyed	6	16.8 (±11.7)	1008 (±702
"	3	Eyed	1	24.4	1464

Table 8. Survival rates and stage of development of brown trout eggs at three bioassay sites on the Clark Fork River during the 1984-85 incubation period.

Date	Site	Egg Type	Percent Survival	Eggs Live,	Dead	Stage of Development (Live Eggs)
1/19-20/84	1	Green	98.1	159	3	100% Green
	2	Green	98.8	163	2	100% Green
	3	Green	95.6	151	7	100% Green
2/8/84	1	Green	95.0	151	8	100% Green
	2	Green	92.0	149	13	100% Green
	3	Green	92.5	149	12	100% Green
/22-24/85	1	Green	89.0	145	18	100% Green
	2	Green	78.8	130	35	100% Green
	3	Green	94.3	150	9	100% Green
	1	Eyed	91.4	148	14	99.3% Eyed,0.7% Sac Fry
	2	Eyed	92.6	150	12	100% Eyed
	3	Eyed	92.0	150	13	100% Eyed
/21,22&25/85	1	Green	92.0	149	13	2.0% Green,96.6% Eyed,1.3% Sac Fry
	2	Green	0.0*	0	162	-
	3	Green	0.0*	0	158	-
	1	Eyed	91.5	150	14	95.3% Eyed,4.7% Sac Fry
	2	Eyed	70.8	114	47	100% Eyed
	3	Eyed	83.9	135	26	98.5% Eyed,1.5% Sac Fry
/14-15/85	1	Green	86.8	46	7	4.3% Green,91.3% Eyed,4.3% Sac Fry
	2	Green	0.0	0	164	-
	3	Green	0.0	0	157	-
	1	Eyed	85.3	139	24	2.2% Eyed,97.8% Sac Fry
	2	Eyed	66.3	108	55	46.3% Eyed,53.7% Sac Fry
	3	Eyed	65.8	106	55	50.9% Eyed,49.1% Sac Fry
/27,29 &	1	Green	91.7	143	13	2.1% Green,94.4% Eyed,3.5% Sac Fry
/2/85	2	Green	0.0	0	162	-
	3	Green	0.0	0	161	-
	1	Eyed	83.2	134	27	100% Sac Fry
	2	Eyed	72.4	110	42	100% Sac Fry
	3	Eyed	48.6	52	55	100% Sac Fry

Green egg bioassay terminated due to egg freeze-up.

Table 9. Cumulative survival rates of brown trout eggs at three bioassay sit on the Clark Fork River during the 1984-85 incubation period.

Date	Site	Cumulative Percent Survival	Cumulative Total Eggs Live	Dead
		Green Egg Bioassay		
11/19-20/84	1	98.1	159	3
	2	98.8	163	2
	3	95.6	151	7
12/08/84	1	96.6	310	11
	2	95.4	312	15
	3	94.0	300	19
1/22-24/85	1	93.6	455	31
	2	89.8	442	50
	3	94.1	450	28
2/21/85	1	93.6	599	41
3/14/85	1	93.1	645	48
3/27/85	1	92.8	788	61
		Eyed Egg Bioassay		
1/22-24/85	1	91.4	148	14
	2	92.6	150	12
	3	92.0	150	13
2/21,22&25/85	1	91.4	298	28
	2	81.7	264	59
	3	88.0	285	39
3/14-15/85	1	89.4	437	52
	2	76.5	372	114
	3	80.6	391	94
3/27/29 & 4/2/85	1	87.8	571	79
	2	75.5	482	156
	3	74.8	443	149

Also, embryo development was significantly slower at the Champion and Cyr sites than at Council Grove. By mid-March, 1985, the eyed egg bioassay was developed to 97.8 percent sac fry at Council Grove compared to 53.7 and 49.1 percent sac fry at Champion and Cyr, respectively (Table 8).

Since water depths and mean velocities remained within acceptable criteria for egg survival during the incubation period at all three bioassay sites, and since intergravel permeability was more favorable for egg survival at Champion and Cyr than at Council Grove, higher egg mortality rates at Champion and Cyr are apparently related to other environmental factors. Intergravel apparent velocity also appeared to have no significant influence on egg mortality since the highest egg mortality rates were found at Cyr, the site with the most favorable apparent velocity conditions for egg survival.

McNeil and Ahnell (1964) working on pink salmon streams in southeastern Alaska found successful egg incubation was impaired where bottom materials contained more than 15 to 20 percent of fine materials passing through an 0.84-mm sieve. Since the percentages of fine materials averaged 6.29, 9.57 and 15.26 percent at the Council Grove, Champion and Cyr eyed egg bioassay sites, respectively, egg survival and embryo development should not have been significantly impaired at these sites by fine materials (Table 10). An average of 11.73 percent ($\pm$ 1.28% S.D.) fine materials was found in three actual brown trout redds located at Council Grove, an area where successful brown trout spawning and incubation is known to occur. Even though fine materials averaged 23.60 percent for the green egg bioassay at Council Grove, a cumulative egg survival rate of 92.8 percent from mid-November, 1984, through late March, 1985, indicated fine materials did not significantly impair egg survival (Tables 9 and 10). It appears brown trout eggs may tolerate higher percentages of fine sediment during their incubation period than salmon.

Heavy metals have been present in the Clark Fork River basin for many years (MDHES 1985). Copper mining and smelting activities in the Butte, Anaconda and Phillipsburg areas, beginning in the late 1800's are the major contributors of metals present in the system today. Since heavy metals can influence egg survival and development, surface and intergravel concentrations of cadmium, copper, zinc, and iron, the predominant heavy metals of concern in the Clark Fork, were monitored at the bioassay sites during the incubation period.

Water quality criteria established by the EPA for protection of freshwater aquatic life are shown in Table 11 for cadmium, copper, zinc and iron. Criteria for iron were established in July, 1976 (EPA 1976). Criteria for zinc have been effective since November 28, 1980 (Federal Register), and revised criteria for cadmium and copper were released July 29, 1985 (Federal Register).

Intergravel concentrations of heavy metals were well below chronic and toxic criteria levels at all three bioassay sites during the 1984-85 incubation period (Tables 11 and 12). Therefore, heavy metals should not have affected egg survival or embryo development at the bioassay sites.

Table 10. Fine substrate composition at green and eyed egg bioassay sites on the Clark Fork River during the 1984-85 incubation period.

Egg Type	Bioassay Site	N	Percentage of materials passing through 0.84-mm sieve (± standard deviation)
Green	1	2	23.60% (± 2.81)
	2	2	13.70% (± 1.67)
	3	2	15.19% (± 4.86)
Eyed	1	1	6.29%
	2	1	9.57%
	3	1	15.26%

Table 11. Water quality criteria for cadmium, copper, zinc and iron established by the U. S. Environmental Protection Agency for protection of freshwater aquatic life.

Metal	EPA Criteria (Total Recoverable Concentrations)
Cadmium	4 day average concentration should not exceed:
chronic criteria	0.66 µg/l at 50 mg/l $CaCO_3$ hardness
"	1.1 " " 100 " " "
	2.0 " " 200 " " "
	1 hour average concentration should not exceed:
acute criteria	1.8 µg/l at 50 mg/l $CaCO_3$ hardness
"	3.9 " " 100 " " "
	8.6 " " 200 " " "
Copper	4 day average concentration should not exceed:
chronic criteria	6.5 µg/l at 50 mg/l $CaCO_3$ hardness
"	12.0 " " 100 " " "
	21.0 " " 200 " " "
	1 hour average concentration should not exceed:
acute criteria	9.2 µg/l at 50 mg/l $CaCO_3$ hardness
"	18.0 " " 100 " " "
	34.0 " " 200 " " "
Zinc	At any time the concentration should not exceed:
acute criteria	180 µg/l at 50 mg/l $CaCO_3$ hardness
"	320 " " 100 " " "
	570 " " 200 " " "
chronic criteria	24 hour average concentration should not exceed:
	47 µg/l
Iron	1.0 mg/l

Table 12. Surface and intergravel concentrations of heavy metals and nutrients at three bioassay sites on the Clark Fork River during the 1984-85 incubation period. Standard deviations are in parentheses.

	Site 1 Council Grove				Site 2 Champion side channel			
	Intergravel		Surface		Intergravel		Surface	
Parameter	Mean	Range	Mean	Range	Mean	Range	Mean	Range
T.S.S.(mg/l)	16.0(±10.8)	4.8-37.8	2.0(±1.0)	1.1-3.0	74.2(±108.8)	0.8-332.3	1.8(±0.1)	1.7-1.9
V.S.S.(mg/l)	3.1(± 2.1)	1.2-8.1	1.2(±0.1)	1.1-1.3	18.4(±16.8)	6.1-52.8	1.4(±0.0)	N=2
Total Alkalinity ($mg/lCaCO_3$)	109.3(±15.2)	68.0-121.0	114.0(±3.3)	109.0-118.0	344.8(±175.6)	133.0-686.0	115.2(±3.9)	109.0-119.0
Total Hardness ($mg/lCaCO_3$)	126.0(±35.1)	44.0-166.0	133.7(±1.5)	132.0-135.0	181.9(±38.4)	131.0-253.0	129.3(±3.2)	127.0-133.0
Total Recoverable								
Cu(mg/l)	<0.01	N=1	<0.01	N=2	<0.01	<0.01-0.01	<0.01	N=2
Fe(mg/l)	0.16	N=1	0.05(±0.0)	N=2	0.35(±0.29)	0.16-0.86	0.07(±0.0)	N=2
Cd(mg/l)	<0.005	N=1	<0.005	N=2	<0.005	N=5	<0.005	N=2
Zn(mg/l)	0.006	N=1	0.006(±0.001)	0.005-0.006	0.012	0.005-0.020	<0.005	N=2
pH	8.06(±0.12)	7.81-8.20	8.31(±0.18)	8.14-8.60	7.87(±0.15)	7.70-8.20	8.23(±0.18)	7.94-8.39
$NH_3asN(mg/l)$	0.013(±0.005)	0.01-0.02	0.01(±0.00)	N=3	0.50(±0.31)	0.02-0.91	0.03(±0.03)	0.01-0.06
$NO_3asN(mg/l)$	0.232(±0.127)	0.142-0.321	0.101(±0.022)	0.085-0.116	0.179(±0.069)	0.130-0.228	0.107(±0.049)	0.072-0.142
$PO_4asP(mg/l)$	0.028(±0.009)	0.021-0.034	0.027(±0.000)	N=2	0.035(±0.010)	0.028-0.042	0.036(±0.009)	0.029-0.042
T.D.S.(mg/l)	211.4(±4.5)	208.2-214.5	214.7(±1.8)	213.4-215.9	213.7(±8.0)	208.0-219.3	225.6(±5.2)	221.9-229.2

Table 12. (Cont.)

Parameter	Site 2 Champion main channel				Site 3 Cyr			
	Intergravel		Surface		Intergravel		Surface	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
T.S.S.(mg/l)	60.1(±18.2)	47.2-73.0	2.7	N=1	12.4(±6.8)	1.9-20.1	2.7(±1.2)	1.8-4.1
V.S.S.(mg/l)	11.2(±1.6)	10.1-12.3	1.6	N=1	2.6(±1.4)	1.0-5.7	1.6(±0.3)	1.2-1.8
Total Alkalinity ($mg/lCaCO_3$)	115.3(±2.75)	112.0-118.0	115.3(±4.7)	110.0-119.0	105.3(±13.5)	76.0-118.0	112.2(±4.0)	107.0-118.0
Total Hardness ($mg/lCaCO_3$)	130.0(±4.2)	127.0-133.0	131.0	N=1	116.0(±18.7)	73.0-134.0	129.0(±8.5)	123.0-135.0
Total Recoverable								
Cu(mg/l)	<0.01	N=1	<0.01	N=1	<0.01	N=1	<0.01	N=2
Fe(mg/l)	0.30	N=1	0.07	N=1	0.10	N=1	0.045(±0.007)	0.04-0.05
Cd(mg/l)	<0.005	N=1	0.005	N=1	<0.005	N=1	<0.005	N=2
Zn(mg/l)	0.03	N=1	0.005	N=1	0.02	N=1	0.0065(±0.002)	0.005-0.008
pH	8.06(±0.19)	7.90-8.33	8.40(±0.10)	8.30-8.50	8.18(±0.10)	8.04-8.32	8.35(±0.10)	
NH_3asN(mg/l)	0.03(±0.02)	0.02-0.04	0.01	N=1	0.01(±0.004)	0.01-0.02	0.01(±0.0)	N=3
NO_3asN(mg/l)	0.21(±0.04)	0.179-0.237	0.108(±0.064)	0.063-0.153	0.179(±0.069)	0.130-0.228	0.110(±0.061)	0.067-0.153
PO_4asP(mg/l)	0.08(±0.04)	0.05-0.10	0.035(±0.008)	0.029-0.040	0.035(±0.010)	0.028-0.042	0.029(±0.004)	0.026-0.031
T.D.S.(mg/l)	226.8(±2.47)	225.0-228.5	224.3(±1.1)	223.5-225.1	213.7(±8.0)	208.0-219.3	215.3(±3.2)	213.0-217.5

Surface concentrations of heavy metals at the bioassay sites were also well below chronic and toxic criteria levels during the incubation period.

Ammonia occurs in natural waters as a normal byproduct of biological degradation of nitrogenous organic matter. It may also reach ground and surface waters through discharge of municipal or industrial wastewater (EPA 1976). In unpolluted waters the concentration of ammonia is very low, usually well under 1 mg/l (MDHES 1985). Elevated concentrations of ammonia are often associated with wastewaters high in organics. In a recent water quality study the Montana Department of Health and Environmental Sciences found Missoula sewage treatment plant effluent contained from 0.8 to 19.3 mg/l in total ammonia. Total ammonia concentrations in the Champion pulp mill effluent ranged from about 2.2 to 8.6 mg/l. Background levels of ammonia in the Clark Fork River are usually less than 0.05 mg/l (MDHES 1985).

The toxicity of ammonia to aquatic life depends on concentration, pH and water temperatures (EPA 1976). A water solution in which ammonia is present contains two forms of the compound, ionized (NH_4+) and un-ionized (NH_3). The equilibria between these two forms of ammonia is directly related to pH and temperature. The un-ionized form is the most toxic to aquatic life. It's concentration increases with a rise either in pH or temperature. The pH range of most natural waters is such that the ionized form, NH_4^+, predominates (MDHES 1985).

The EPA recommends a maximum concentration of 0.02 mg/l NH_3 (un-ionized ammonia) for protection of freshwater aquatic life (EPA 1976). Willingham et al. (1979) agreed the criterion selected by EPA was appropriate for freshwater salmonid fishes. Concentrations of un-ionized ammonia, NH_3, ranged from 0.0002 to 0.0006 mg/l in surface water samples collected at the three bioassay sites on the Clark Fork River during the 1984-85 incubation period (Table 13). Intergravel concentrations ranged from 0.0001 to 0.0074 mg/l NH_3. The highest intergravel and surface water concentrations of un-ionized ammonia were consistently found at the Champion bioassay site. However, since the maximum intergravel concentration of un-ionzied ammonia reached only 37% of the EPA criterion, ammonia should not have affected egg survival or embryo development at the bioassay sites during the 1984-85 incubation period. This conclusion is based on un-ionized ammonia concentrations alone under conditions which are not complicated by the presence of other toxins, low dissolved oxygen concentrations or other factors which could cause synergistic effects (Willingham et al. 1979).

Dissolved oxygen historically has been a major constituent of interest in water quality investigations (EPA 1976). Dissolved oxygen concentrations are an important measure of existing water quality and the ability of a body of water to support a well balanced aquatic fauna. In order for trout eggs and embryos to properly develop in the intergravel environment, they must receive an ample supply of well oxygenated water. Embryonic and larval stages are especially vulnerable to reduced oxygen concentrations because their ability to extract oxygen from the water is not fully developed, and they cannot move away from adverse conditions.

Table 13. Surface and intergravel concentrations of ammonia at three bioassay sites on the Clark Fork River during the 1984-85 incubation period.

Date	Site[1/]	Sample Source[2/]	Water Temp °C	pH	Total Ammonia (mg/l as N)	Un-ionized Ammonia @5°C (mg/l NH_3)
11/15-16/84	1	I-1	2.2	8.09	<0.01	<0.0002
		I-2a	2.2	7.95	0.02	0.0002
		I-2b	2.2	8.04	0.01	0.0001
		I-3	2.3	7.81	<0.01	<0.0001
		Surface	2.0	8.14	0.01	0.0002
	2-SC	I-1	3.2	7.86	0.31	0.0032
		I-2	4.4	7.70	0.91	0.0065
		I-3	4.5	7.77	0.58	0.0051
		Surface	2.5	8.34	0.02	0.0006
	3	I-1	3.3	8.09	0.01	0.0002
		I-2a	3.1	8.07	<0.01	<0.0002
		I-2b	3.1	8.04	0.01	0.0001
		I-3	3.2	8.32	0.02	0.0006
		Surface	2.8	8.39	<0.01	<0.0003
12/13-14/85	1	I-1	2.0	8.05	0.01	0.0002
		I-2	2.5	8.10	<0.01	<0.0002
		I-3	2.5	8.17	0.01	0.0002
		Surface	1.0	8.30	0.01	0.0003
	2-SC	I-1	1.0	7.80	0.80	0.0070
		I-2	1.0	7.78	0.58	0.0051
		I-3	0.6	7.97	0.62	0.0074
		Surface	0.0	7.94	0.06	0.0006
	2-MC	I-1	0.0	8.00	0.04	0.0005
	3	I-1	1.0	8.30	<0.01	<0.0003
		I-2	1.0	8.23	<0.01	<0.0002
		I-3	1.0	8.11	<0.01	<0.0002
		Surface	1.0	8.30	0.01	0.0003
1/28/85	1	I-1	2.0	8.03	0.02	0.0002
		Surface	1.0	8.19	0.01	0.0002
	2-SC	I-1	1.0	7.92	0.02	0.0002
		Surface	0.5	8.39	0.01	0.0003
	2-MC	I-1	0.5	8.33	0.01	0.0003
		Surface	0.5	8.38	0.01	0.0003
	3	I-1	0.5	8.20	<0.01	<0.0002
		Surface	0.0	8.25	<0.01	<0.0003
3/05/85	2-SC	I-1	4.0	7.80	0.18	0.0016

[1/] Sample Site: 1 = Council Grove, 2-SC = Champion Side Channel (green egg bioassay), 2-MC = Champion Main Channel (eyed egg bioassay), 3 = Cyr

[2/] Water Sample Source: I-1 = Intergravel standpipe number one, I-2a = Intergravel standpipe number two, replicate a, etc.

For salmonid spawning beds, EPA (1976) recommends a minimum concentratio of dissolved oxygen of 5.0 mg/l in the interstitial water of the gravel. Dav et al. (1979) concluded this criterion was rather naive and open to criticism In areas where a high level of dissolved oxygen predominates naturally, the level of 5.0 mg/l as an oxygen minimum may be a very permissive criterion allowing considerable debilitation of embryos or larvae to occur. Although embryonic and larval stages of some species can develop at oxygen concentrations as low as 2.5 to 3 mg/l, the effects of a reduced oxygen concentration even as high as 5 or 6 mg/l can cause partial mortality or retard development in other species (EPA 1976). Alderdice, Wickett and Brett (1958) reported the critical level of dissolved oxygen for chum salmon embryos to be 0.72 mg/l shortly after fertilization. The value increased during the incubation period to 7.19 mg/l shortly before hatching. Hayes et al. (1951) conducted experiments on Atlantic salmon embryos, incubated at 10°C, and found the critical level to be 2.8 mg/l 20 days after fertilization and 7.1 mg/l just before hatching. Shumway (1960) did not determine a critical level for dissolved oxygen but found significant size differences in coho salmon fry when embryos were reared at 2.5, 4.0 and 10.3 mg/l dissolved oxygen. Phillip and Campbell (1962) found that dissolved oxygen concentration necessary for the embryonic survival of coho salmon and steelhead trout in costal stream gravel beds was greater than had been previously suspected. Howse and Whitt (1970) concluded that mean dissolved oxygen concentrations in gravel necessary for a high survival of coho salmon and steelhead trout embryos may exceed 8.0 mg/l.

Intergravel concentrations of dissolved oxygen at bioassay sites on the Clark Fork River were consistently lower than surface water concentration during the 1984-85 incubation period (Table 14). The lowest intergravel dissolved oxygen concentration observed at the Council site for both the green and eyed egg bioassays was 7.2 mg/l (Table 15). At the Champion site intergravel dissolved oxygen concentrations reached minimums of 0.4 mg/l for the green egg bioassay and 3.9 mg/l for the eyed egg bioassay. Minimum intergravel dissolved oxygen concentrations of 5.7 and 4.2 mg/l were observed at the Cyr green and eyed egg bioassays, respectively.

It appears probable that brown trout egg survival and embryo development were negatively impacted by low intergravel dissolved oxygen concentrations at Champion for both the green and eyed egg bioassays and at Cyr for the eyed egg bioassay (Tables 8 and 14). Dissolved oxygen concentrations at these sites during the incubation period reached low levels which even violated the relatively permissive 1976 EPA criteria (EPA 1976). Cumulative brown trout egg mortality rates at the Champion and Cyr eyed egg bioassay sites where dissolved oxygen concentrations reached low levels of 3.9 and 4.2 mg/l, respectively, were approximately 100% greater than cumulative egg mortality rates at the Council Grove eyed egg bioassay where dissolved oxygen reached a low concentration of only 7.2 mg/l (Tables 9 and 15). Also, as mentioned earlier, embryo development at Champion and Cyr was significantly slower than at Council Grove (Table 8). Since the green egg bioassays at Champion and Cyr were terminated in February due to egg freeze-up, long term egg survival and embryo development rates at these sites could not be evaluated. However, by late January, 1985, egg mortality

Table 14. Intergravel and surface dissolved oxygen concentrations at three brown trout egg bioassay sites on the Clark Fork River during the 1984-85 incubation period. Standard deviations are in parentheses.

Site	Date	Sample Source	Egg Type	N	Dissolved Oxygen (mg/l)
1	11/15/84	Surface	-	1	11.4
1	"	Gravel	Green	4	10.9 (±0.3)
2	"	Surface	-	1	13.5
2	"	Gravel	Green	3	4.9 (±3.0)
3	11/16/84	Surface	-	1	13.9
3	"	Gravel	Green	4	12.3 (±0.5)
2	12/13/84	Surface	-	1	13.0
2	"	Gravel	Green	1	3.3
2	"	Gravel	Eyed	1	8.5
1	12/17/84	Surface	-	1	11.4
1	"	Gravel	Green	3	10.2 (±0.3)
2	"	Surface	-	1	14.1
2	"	Gravel	Green	3	10.3 (±2.1)
3	12/14/84	Surface	-	1	13.6
3	"	Gravel	Green	3	13.1 (±0.3)
1	1/30/85	Surface	-	1	12.3
1	"	Gravel	Green & Eyed	5	10.6 (±1.1)
2	1/29/85	Surface	-	2	13.7 (±0.1)
2	"	Gravel	Green	2	5.8 (±1.5)
2	"	Gravel	Eyed	2	11.7 (±1.1)
3	"	Surface	-	1	13.0
3	"	Gravel	Green	2	10.2 (±0.5)
3	"	Gravel	Eyed	3	10.7 (±1.2)
1	2/28/85	Surface	-	-	-
1	"	Gravel	Green & Eyed	5	8.7 (±0.7)
2	"	Surface	-	2	12.7 (±0.1)
2	"	Gravel	Green	3	5.2 (±2.6)
2	"	Gravel	Eyed	3	9.5 (±2.0)
3	3/1/85	Surface	-	1	11.9
3	"	Gravel	Green	5	8.2 (±1.6)
3	"	Gravel	Eyed	4	6.0 (±1.3)
1	4/1/85	Surface	-	1	12.6
1	"	Gravel	Green & Eyed	5	8.7 (±1.5)
2	"	Surface	-	1	11.7
2	"	Gravel	Green	3	0.7 (±0.4)
2	"	Gravel	Eyed	3	8.1 (±3.9)
3	"	Surface	-	1	11.4
3	"	Gravel	Green	3	8.1 (±2.2)
3	"	Gravel	Eyed	3	7.4 (±1.2)

Table 15. Overall means and ranges of intergravel and surface dissolved oxygen concentrations at three brown trout egg bioassay sites on the Clark Fork River during the 1984-85 incubation period. Standard deviations in paren

Site	Sample source	Egg type	N	Mean Dissolved Oxygen (mg/l)	Dissolved Oxygen (mg/l)
1	Surface	-	4	11.9 (± 0.6)	11.4 - 12.6
	Gravel	Green & eyed	21	9.6 (± 1.2)	7.2 - 12.3
2	Surface	-	8	13.1 (± 0.8)	11.7 - 14.1
	Gravel	Green	15	5.2 (± 3.6)	0.4 - 12.2
	Gravel	Eyed	9	9.4 (± 2.6)	3.9 - 12.5
3	Surface	-	5	12.8 (± 1.1)	11.4 - 13.85
	Gravel	Green	17	10.2 (± 2.5)	5.7 - 13.5
	Gravel	Eyed	10	7.8 (± 2.3)	4.2 - 11.7

at the Champion green egg bioassay site was approximately 100% higher than at the green egg bioassays at Council Grove and Cyr (Table 8). During the incubation period prior to late January, intergravel dissolved oxygen had reached a low concentration of 3.3 mg/l at the Champion green egg bioassay compared to low concentrations of 10.2 mg/l at both the Council Grove and Cyr green egg bioassays (Table 14). These findings indicate high brown trout egg mortality and retarded embryo development were probably associated with low intergravel dissolved concentrations found at bioassay sites located downstream from the pulp mill effluent discharge.

Elevated concentrations of sulfate, sodium and chloride ions in water samples collected from the intergravel environment at the Champion and Cyr bioassay sites suggest Champion effluent affects intergravel water quality for a distance of at least 25.6 miles downstream from the effluent discharge (Table 16). Surface water concentrations of these ions were also higher at Champion and Cyr, downstream from the discharge, than at Council Grove, the upstream control.

Brown trout fry emergence traps installed at each of the three bioassay sites as described in the methods section did not provide any useable data, since no fry had emerged from the gravel prior to high water, and the traps could not be reached during high water when emergence occurred. For this reason, brown trout egg survival and embryo development data given in this report are based entirely on the fiberglass egg bags buried in the substrate at each bioassay site.

Semi-volatile organic compounds and hydrogen sulfide are known fish toxicants which could influence brown trout egg survival and embryo development. Since concentrations of these parameters were not monitored at the bioassay sites during the 1984-85 incubation period, it was decided they should be monitored during the 1985-86 brown trout egg incubation period to determine whether intergravel concentrations found in the Clark Fork River are high enough to affect egg survival or embryo development. Findings are presented in the following section of this report.

1985-86 Brown Trout Egg Incubation Period

Since it appeared that brown trout egg survival and embryo development were impaired at the two bioassay sites located downstream from the pulp mill effluent discharge during the 1984-85 incubation period due to water quality factors, it was decided that intergravel and surface water quality monitoring should be expanded to include additional sites during the 1985-86 brown trout egg incubation period. Because of the increased time required to monitor intergravel and surface water quality at the additional sites, the egg bioassay was not repeated during the 1985-86 incubation period.

Table 16. Major cation/anion concentrations from brown trout egg bioassay site in the Clark Fork River during the 1984-85 incubation period.

Date	Site	Sample Source	Mean concentration (mg/l)					
			SO_4^{-2}	Cl^-	Na^+	K^+	Ca^{+2}	Mg^{+2}
3/5/85	1	Gravel	21.2	3.1	7.5	2.3	30.0	11.1
		Surface	21.4	3.1	7.3	2.1	30.6	11.0
	2	Gravel-side channel	142.0	43.1	144.0	4.5	34.9	17.7
		Surface-side channel	24.0	5.0	13.6	2.2	30.0	11.0
		Gravel-main river	21.6	4.9	12.6	2.3	30.3	9.7
		Surface-main river	21.6	4.9	12.6	2.3	30.3	9.7
	3	Gravel	24.5	4.1	10.2	2.5	29.7	10.9
		Surface	21.0	4.1	10.1	2.4	30.0	10.8
4/2/85	1	Gravel	22.7	2.8	6.6	2.0	30.9	10.2
		Surface	25.9	2.7	7.1	1.8	31.8	10.4
	2	Gravel-side channel	404.0	123.0	388.0	8.5	68.2	28.5
		Surface-side channel	31.0	4.1	11.4	1.9	30.8	10.0
		Gravel-main river	30.2	4.1	11.4	2.0	31.8	10.5
		Surface-main river	31.2	4.0	11.4	1.8	31.2	10.0
	3	Gravel	21.9	3.6	9.1	2.1	29.8	10.1
		Surface	27.0	3.5	9.3	1.8	30.6	9.6

Study Sites

Eight locations in the Clark Fork River were chosen for intergravel and surface water quality monitoring sites during the 1985-86 brown trout egg incubation period (Table 17). This provided a total of three monitoring sites upstream from the pulp mill effluent discharge to serve as controls, Milltown Dam, Council Grove and Harper's Bridge; two sites downstream from the pulp mill effluent discharge to serve as exposure sites within the 10.4 - mile mixing zone, Champion and Bud King's; and three sites downstream from the pulp mill effluent discharge to serve as exposure sites below the 10.4 - mile mixing zone, Ninemile, Cyr and Superior.

Methods

Permeability of the gravel bed at each monitoring site was calculated during the brown trout egg incubation period in mid-December, 1985, and late January, 1986, using Mark VI standpipes as described by Terhune (1958). Three standpipes were positioned in a triangular configuration on the gravel bar at each monitoring site to determine mean permeability at the site. All permeabilities were converted to a standard temperature ($10^{o}C$) to facilitate comparisons of measurements.

Groundwater flow through the substrate, or apparent velocity, was measured directly with a seepage meter (Lee 1977, Lee and Cherry 1979). To correct for the low volume of inflow observed with seepage meters used during the 1984-85 monitoring period, larger seepage meters were employed. These consisted of the tops of 55 - gallon metal drums.

Metal Mark VI standpipes and a hand operated rotary pump were used according to procedures described earlier to collect intergravel water quality samples for all parameters except heavy metals. Water samples for intergravel monitoring of heavy metals were collected from seepage meters. To prevent contamination of the heavy metals water samples from the metal seepage meters, the meters were coated with epoxy resin and overcoated with an epoxy-based paint. Tests with distilled water blanks indicated this procedure prevented contamination of the samples.

Surface and intergravel water quality were monitored at approximately one month intervals during the 1985-86 brown trout egg incubation period at each study site. Parameters measured included pH, alkalinity, total dissolved solids, major cation/anion concentrations including sulfate, chloride, sodium, potassium, calcium and magnesium, total conductivity, dissolved oxygen, total and volatile suspended solids and total recoverable concentrations of copper, cadmium, zinc and iron. Water analyses were performed by the Chemistry Department of the University of Montana, except for measurements of total and volatile suspended solids and total recoverable concentrations of heavy metals, which were made by the

Table 17. Study site names, river mileage locations and legal descriptions for intergravel and surface water quality monitoring during the 1985-86 brown trout egg incubation period.

Site No.	Site Name	Approximate River Mile	Legal Description
1	Milltown Dam	364.3	T13N,R18W,S20A
2	Council Grove	343.5	T13N,R20W,S06DCC
3	Harper's Bridge	341.4	T14N,R21W,S35AD
4	Champion	338.6	T14N,R21W,S14BBB
5	Bud King's	334.6	T14N,R21W,S03
6	Ninemile	324.0	T15N,R22W,S32
7	Cyr	313.0	T14N,R23W,S06BCC
8	Superior	286.8	T16N,R26W,S03AC

Montana Department of Health and Environmental Sciences laboratory in Helena, and measurements of dissolved oxygen, which were determined in the field using the azide modification of the Winkler method. The intensity of heavy metals sampling was reduced after it was determined that heavy metals were not present in high enough concentrations to cause significant egg mortality at any of the study sites.

Surface and intergravel water samples for determining the possible presence and concentration of semi-volatile organic compounds were collected on April 17, 1986, near the end of the brown trout egg incubation period at Milltown Dam, Harper's Bridge, Champion and Cyr. Analyses were performed by EPA's Region VIII laboratory in Denver.

Intergravel water samples were collected on April 14-15, 1986, at Milltown Dam, Harper's Bridge, Champion and Cyr to determine the possible presence and concentration of hydrogen sulfide. Analyses were performed by the Montana Department of Health and Environmental Siences laboratory in Helena.

Results

Intergravel permeability was measured during the 1985-86 brown trout egg incubation period to assess permeability and potential egg survival or embryo development problems related to permeability at additional monitoring sites. Intergravel permeability varied from a low of 43 cm/hr (0.7 cm/min) in mid-December, 1985, at Council Grove to a high of 2734 cm/hr (45.6 cm/min) in late January, 1986, at Milltown Dam (Table 18). The ranges of permeabilities measured at eight monitoring sites in the Clark Fork during 1985-86 brown trout egg incubation period were similar to permeability ranges observed at three monitoring sites during the 1984-85 egg incubation period (Tables 7 and 18). Average permeabilities observed during both years were low when compared to average permeabilities found in other streams (McNeil and Ahnell 1964). However, findings from the brown trout egg bioassay conducted during the 1984-85 incubation period indicated egg survival and embryo development were not impaired by low intergravel permeabilities found in the Clark Fork.

Due to a variety of seepage meter design problems, no reliable measurements of intergravel apparent velocity were obtained during the 1985-86 brown trout egg incubation period. Apparent velocity readings obtained from seepage meters used during the 1985-86 monitoring period were judged to be inaccurate because readings from several meters could not be duplicated on the same date. Larger seepage meters were used during the 1985-86 monitoring period in an attempt to correct for low volumes of flow obtained with smaller seepage meters used during the 1984-85 monitoring period. While the problem of low flow volumes was corrected using larger meters, flow volumes and calculated apparent

Table 18. Permeabilities at 10°C at eight stations on the Clark Fork River during the 1985-86 brown trout incubation period. Standard deviations are in parentheses.

Date	Site	Number (N)	Permeability K_{10}(cm/hr)
12/16-20/85	Milltown Dam	3	1352 (± 971)
	Council Grove	3	43 (± 7.4)
	Harper's Bridge	3	123 (± 14.5)
	Champion S.C.	3	990 (± 1241)
	Champion M.C.	3	326 (± 406)
	Bud King's	Not Measured	
	Ninemile	Not Measured	
	Cyr	3	233 (± 180)
	Superior	3	221 (± 94.3)
1/21-24/86	Milltown Dam	3	2734 (± 2392)
	Council Grove	3	425 (± 484)
	Harper's Bridge	3	332 (± 247)
	Champion S.C.	3	1141 (± 744)
	Champion M.C.	3	684 (± 742)
	Bud King's	No Valid Measurements	
	Ninemile	3	881 (± 562)
	Cyr	3	203 (± 146)
	Superior	3	279 (± 62.6)

velocities were inconsistent. Intergravel velocities were measured during the 1985-86 incubation period in an attempt to develop a better seepage meter rather than because of any concern that apparent velocities found in the Clark Fork could affect egg survival. Findings from the brown trout egg bioassay conducted during the 1984-85 incubation period indicated apparent velocities found in the Clark Fork do not impair egg survival or embryo development.

Concentrations of heavy metals in intergravel and surface water samples were well below chronic and toxic criteria levels at all eight monitoring sites during the 1985-86 brown trout egg incubation period (Tables 11 and 19). Therefore, heavy metals should not have affected egg survival or embryo development at the monitoring sites.

Intergravel concentrations of dissolved oxygen during the 1985-86 brown trout egg incubation period at the eight monitoring sites on the Clark Fork River were generally lower than surface water concentrations (Table 20). For salmonid spawning beds, EPA (1976) recommends a minimum concentration of dissolved oxygen of 5.0 mg/l in the interstitial water of the gravel. Egg survival studies have shown this is a relatively permissive criteria (Davis et al. 1979, Alderdice, Wickett and Brett 1958, Hayes et al. 1951, Shumway 1960, Phillips and Campbell 1962, Howse and Whitt 1970).

Intergravel dissolved oxygen concentrations reached low levels which even violated the relatively permissive EPA criteria during the 1985-86 brown trout egg incubation period at Milltown Dam, Champion (side channel), Erskine, Cyr and Superior. Intergravel dissolved oxygen reached minimum concentrations of 0.68, 0.00, 0.12, 0.38 and 4.94 mg/l at each of these monitoring sites, respectively (Table 20).

It appears likely that 100 percent egg mortality would have occurred during the 1985-86 incubation period at Milltown Dam, Champion (side channel), Erskine and Cyr, and that egg survival and embryo development would have been impaired at Superior due to low dissolved oxygen concentrations in the intergravel environment. With the exception of the Milltown Dam site, low dissolved oxygen concentrations occurred during the 1985-86 incubation period only at monitoring sites located downstream from the Champion pulp mill.

The following findings indicate the Milltown Dam station should probably be excluded as a valid upstream control site for evaluating potential impacts of Champion pulp mill effluent discharges on dissolved oxygen concentrations in the intergravel environment. Intergravel dissolved oxygen concentrations at Milltown Dam were well above established criteria from mid-December, 1985, through late February, 1986, and below criteria only in mid-April, 1986. Low dissolved oxygen concentrations in mid-April at Milltown Dam were probably related to anaerobic conditions which may have developed on the bottom of Milltown Reservoir during the late winter of 1985-86. Intergravel dissolved oxygen concentrations were relatively consistent during the egg incubation period at the other

Table 19. Intergravel and surface toxic metals concentrations from Clark Fork River monitoring stations during the 1985-86 brown trout egg incubation period.

Station	Date	Sample Source	T.S.S. mg/l	V.S.S. mg/l	Total Recoverable Copper mg/l	Iron mg/l	Cadmium mg/l	Zinc mg/l
Milltown	12-16-85	Surface	5.8	1.6	<.01	.06	-	-
		Intergravel	0.9	0.9	<.01	.03	-	-
	1-22-86	Surface	4.8	1.2	<.01	.09	<.005	.014
		Intergravel	2.7	0.8	<.01	.08	<.005	.010
Council Grove	12-17-85	Surface	2.5	1.3	<.01	.04	-	-
		Intergravel	1.3	1.1	<.01	.03	-	-
	1-22-86	Surface	7.6	1.7	<.01	.12	-	-
		Intergravel	4.5	1.2	<.01	.11	-	-
Harper's Bridge	1-24-86	Surface	6.1	1.4	<.01	.08	-	-
		Intergravel	5.2	1.2	<.01	.10	-	-
Champion Main Channel	12-24-85	Surface	2.2	1.4	<.01	.05	-	-
		Intergravel	3.3	1.8	<.01	.05	-	-
	1-21-86	Surface	11.4	2.7	<.01	.21	-	-
		Intergravel	2.5	1.0	<.01	.12	-	-
Champion Side Channel	12-24-85	Surface	1.7	1.3	<.01	.06	-	-
		Intergravel	6.7	2.7	<.01	.09	-	-
	1-21-86	Surface	12.0	3.1	<.01	.20	-	-
		Intergravel	3.0	1.5	<.01	.60	-	-
Bud King's	1-24-86	Surface	3.1	1.0	<.01	.06	-	-
		Intergravel	4.9	1.3	<.01	.10	-	-
Cyr	12-24-85	Surface	2.1	1.1	<.01	.04	-	-
		Intergravel	9.4	2.6	<.01	.07	-	-
	1-23-86	Surface	5.6	1.3	<.01	.09	-	-
		Intergravel	9.5	2.2	<.01	.02	-	-
Superior	1-23-86	Surface	9.0	2.2	<.01	.12	-	-
		Intergravel	19.8	3.7	<.01	.13	-	-

Table 20. Intergravel and surface dissolved oxygen concentrations from Clark Fork River monitoring stations during the 1985-86 brown trout egg incubation period.

tation	Date	Intergravel DO-Pipe No. 1	2	3	Surface DO	Intergravel Water Temp. 1	2	3	Surface Temp.
illtown	12-16-85	10.80	12.00	11.40	12.00	34	33	34	32.5
ouncil Grove	12-17-85	11.20	12.60	12.60	13.60	35	35	35	34
arper's Bridge	12-19-85	12.36	12.78	10.26	10.12	33	32	32	32
hampion S.C.	12-18-85	0.00	0.00	0.00	13.18	39	39	37	34
hampion M.C.	12-18-85	7.88	10.02	12.36	11.46	34	34	34	34
rskine	12-19-85	0.12	0.18	0.16	3.42	37	37	36	34
inemile	Not Measured								
yr	12-20-85	9.62	8.92	4.76	13.14	34	34	33	33
uperior	12-20-85	6.94	6.12	6.54	13.10	36	35	36	33
illtown	1-22-86	10.68	8.56	8.94	9.58	33	33	33	33
ouncil Grove	1-22-86	10.82	11.22	11.36	12.70	38	35	35	35
arper's Bridge	1-24-86	13.60	13.34	12.22	13.84	38	38	38	36
hampion S.C.	1-21-86	0.00	0.00	0.00	12.22	44	43	42	36
hampion M.C.	1-21-86	8.48	9.40	9.14	11.36	37	37	37	37
ing's	1-24-86	12.66	11.36	12.22	11.58	37	37	37	36
inemile	1-24-86	11.78	12.30	12.30	12.14	35	36	36	35
yr	1-23-86	6.32	0.38	1.04	11.14	38	38	39	33
uperior	1-23-86	4.94	6.84	7.66	12.86	39	36	37	34
illtown	2-24-86	8.04	10.82	9.78	12.18	35	35	35	35
ouncil Grove	Not Measured								
arper's Bridge	2-24-86	11.26	12.34	8.18	10.44	39	38	39	38
hampion S.C.	Not Measured								
hampion M.C.	Not Measured								
ing's	2-24-86	11.24	8.82	10.46	10.72	40	39	39	39
inemile	Not Measured								
yr	Not Measured								
uperior	Not Measured								
illtown	4-14-86	2.24	0.68	1.04	12.10	42	42	42	40
ouncil Grove	4- 8-86	11.34	11.52	10.76	11.76	48	48	48	48
arper's Bridge	4-14-86	7.90	7.16	9.38	12.14	44	44	44	44
hampion S.C.	4-15-86	0.00	0.00	0.00	10.86	45	45	45	44
hampion M.C.	4-15-86	11.28	11.00	10.50	11.08	45	45	45	44
ing's	4-17-86	8.22	10.78	9.74	11.34	48	48	48	47
inemile	4-17-86	10.46	10.92	10.56	10.82	47	47	47	47
yr	4-15-86	3.94	4.58	4.72	11.14	46	46	46	45
uperior	4-17-86	7.20	6.94	7.16	11.02	47	46	46	46

monitoring stations. The Milltown Dam monitoring station was located about 300 meters downstream from the dam in an area where considerable groundwater upwelling occurred as evidenced by a seepage meter installed at the site. The relatively high rate of groundwater upwelling was apparently due to hydraulic head created by Milltown Reservoir. Dye tests indicated relatively high rates of groundwater upwelling occurred in a localized zone from Milltown Dam to about 500 meters downstream from the dam. For this reason the Milltown Dam monitoring station was probably not representative of most of the river reach downstream from the dam.

The EPA criterion for intergravel dissolved oxygen concentration was violated at four of six, or 67 percent, of the monitoring sites located downstream from the pulp mill effluent discharge during the 1985-86 brown trout egg incubation period (Table 20). These sites included Champion and Erskine located within the pulp mill effluent mixing zone and Cyr and Superior located 15.2 and 41.4 miles downstream from the end of the mixing zone, respectively.

These findings indicate trout egg survival and embryo development are probably significantly impaired by low intergravel dissolved oxygen concentrations in many potential spawning areas located downstream from the Champion pulp mill effluent discharge.

Elevated concentrations of sulfate, sodium and chloride ions were usually found in intergravel water samples collected during the 1985-86 incubation period at monitoring stations located downstream from the pulp mill effluent discharge (Table 21). Since Champion effluent contains very high concentrations of these ions, this finding suggests Champion effluent affects intergravel water quality as far downstream as the Superior monitoring station, 51.8 miles below the pulp mill effluent discharge. Similar increases in intergravel concentrations of common ions were observed at monitoring stations located downstream from the pulp mill during the 1984-85 brown trout egg incubation period.

Surface and intergravel water samples for determining the possible presence and concentration of semi-volatile organic compounds were collected on April 17, 1986, near the end of the brown trout egg incubation period at Milltown Dam, Harper's Bridge, Champion and Cyr. Semi-volatile organic compounds which could be found in pulp mill wastes include resin acids and phthalate esters. The potential toxicity of these constituents to aquatic life has been well documented (EPA 1976, Mayer et al. 1979, MDHES 1985).

While resin acids were not detected at the monitoring sites, phthalate esters were found in the surface water at Harper's Bridge, in the intergravel water at Champion and in surface and intergravel water at Cyr (Table 22). EPA recommends maximum total concentrations of phthalate esters of 3.0 µg/l (chronic criteria) and 940 µg/l (acute criteria) for the protection of freshwater aquatic life (Federal Register, November 28, 1980).

Table 21. Intergravel water quality at eight monitoring stations on the Clark Fork River during the 1985-86 brown trout egg incubation period.

Parameter	Date	Monitoring Site 1/ 1 2/ I	1 3/ S	2 I	2 S	3 I	3 S	4S I	4S S	4M I	4M S	5 I	5 S	6 I	6 S	7 I	7 S	8 I	8 S
pH	1	8.1	8.2	8.1	8.3	8.2	8.2	7.7	8.2	8.2	8.3	7.6	7.7	-	-	7.9	8.3	8.1	8.3
	2	8.1	8.1	7.9	8.1	8.3	8.2	8.0	8.0	7.8	8.0	8.1	8.2	8.0	8.1	7.4	8.1	7.9	8.1
	3	7.7	8.1	7.8	8.1	7.5	8.1	8.0	8.1	7.9	8.2	8.0	8.2	7.8	8.1	7.6	8.2	8.3	8.3
	4	7.7	8.1	8.2	8.3	7.6	8.1	7.8	8.0	8.0	8.0	7.8	8.2	8.0	8.1	7.5	8.0	7.8	8.1
Total Alk. (mg/l)	1	151.7	151.3	132.2	132.2	128.6	128.1	839.8	131.8	133.5	132.6	198.9	186.5	-	-	132.9	130.7	250.3	127.9
	2	152.8	152.4	129.2	129.2	130.3	129.2	903.5	126.2	130.3	126.9	132.9	134.4	129.9	131.1	151.3	127.7	233.0	127.7
	3	151.3	108.9	98.4	97.1	104.1	86.1	900	91.3	92.5	92.5	94.3	92.5	74.6	75.1	143.2	88.7	259.6	89.1
	4	143.1	102.6	98.8	97.3	82.6	83.8	793.5	88.3	89.0	90.2	89.5	91.0	82.7	83.8	233.4	82.7	213.5	89.1
T.D.S. (mg/l)	1	225.5	224.7	206.1	209.1	203.7	204.5	1856.5	214.4	217.0	213.6	288.6	273.8	-	-	211.9	208.8	357.9	202.4
	2	239.2	239.0	201.9	201.4	204.0	200.0	2101.2	206.8	206.0	203.7	212.7	212.6	206.4	208.7	232.6	201.6	335.8	195.6
	3	228.7	166.0	149.3	146.9	161.9	129.0	2244	139.8	143.8	143.0	145.5	143.1	111.4	112.4	240.4	134.4	366.3	129.8
	4	208.0	143.3	148.6	146.5	122.9	124.3	1907	140.8	140.0	142.8	140.0	141.8	125.0	127.6	350.9	126.0	304.7	133.7
Cl- (mg/l)	1	1.31	1.31	2.4	2.3	2.2	2.2	133.6	3.6	3.5	3.2	2.6	2.7	-	-	3.0	3.0	2.9	2.9
	2	2.3	2.4	2.9	2.7	2.4	2.3	161	3.9	4.0	3.9	3.7	3.2	3.5	3.6	3.2	3.8	3.3	3.4
	3	2.01	1.91	1.91	1.87	2.23	1.66	145	2.42	2.44	2.26	2.34	2.26	2.15	1.83	2.98	2.03	2.58	1.81
	4	1.09	0.77	1.45	1.41	1.14	1.10	129	2.40	2.40	2.48	2.17	2.15	1.72	1.81	4.03	1.70	2.44	1.68
SO_4^{-2} (mg/l)	1	20.4	19.7	21.7	24.4	23.8	24.4	338	25.9	25.5	25.4	19.9	20.0	-	-	24.4	24.4	21.9	22.5
	2	27.3	27.4	20.7	20.6	21.7	19.3	411	21.9	20.2	21.3	23.8	22.7	21.6	23.4	21.7	21.3	20.0	16.0
	3	20.9	16.0	13.0	12.6	17.1	10.1	509	11.2	13.7	13.4	13.3	13.4	8.4	8.7	36.1	11.2	18.1	8.6
	4	15.0	6.7	13.0	12.8	10.1	9.9	387	14.3	13.8	14.7	14.1	13.5	9.9	11.2	30.8	10.8	17.2	10.3

Table 21. (cont.) Intergravel water quality at eight monitoring stations on the Clark Fork River during the 1985-86 brown trout egg incubation period.

Parameter	Date	Monitoring Site 1/ 1 I	1 S	2 I	2 S	3 I	3 S	4S I	4S S	4M I	4M S	5 I	5 S	6 I	6 S	7 I	7 S	8 I	8 S
	2/ 3/																		
+2 Ca (mg/l)	1	35.1	35.5	31.8	32.2	31.6	32.4	62	30.4	32.0	30.4	43.8	42.0	-	-	31.2	30.8	56.4	30.0
	2	37.2	37.2	31.0	30.8	32.4	32.1	68	30.1	29.1	29.5	32.1	32.1	32.0	30.9	35.6	28.4	55.1	31.2
	3	37.8	23.9	21.8	21.6	24.3	18.9	67	19.8	20.4	20.2	21.0	20.4	15.4	15.5	37.4	19.1	63.8	19.3
	4	34.6	22.0	22.4	22.2	18.9	18.9	49.2	20.4	19.4	19.6	19.5	20.4	18.2	18.0	51.5	18.4	51.0	19.5
+2 Mg (mg/l)	1	11.0	10.9	9.6	9.7	9.2	9.3	22.1	9.3	8.8	9.0	12.9	12.8	-	-	9.4	9.0	17.0	9.1
	2	11.6	11.5	9.3	9.3	9.0	8.9	25.2	8.4	8.4	8.5	9.0	9.1	8.9	9.0	10.6	8.8	15.6	6.9
	3	10.5	7.9	6.8	6.9	7.3	5.9	19.0	6.1	6.0	6.1	6.0	6.2	5.2	5.2	11.3	6.3	15.6	6.4
	4	8.6	7.5	7.2	7.2	5.4	5.6	13.6	5.6	5.6	5.7	5.8	6.1	5.5	5.6	17.0	5.6	13.1	6.1
+ Na (mg/l)	1	4.6	4.6	6.7	6.6	6.6	6.4	451	11.6	11.5	11.2	8.4	8.1	-	-	9.3	9.0	7.2	8.4
	2	6.2	6.2	6.7	6.7	6.4	6.4	522	11.4	11.1	10.6	9.3	9.2	9.0	8.9	7.9	9.2	6.5	8.1
	3	4.9	5.2	5.2	4.9	5.6	4.6	587	7.3	6.7	6.7	6.5	6.5	3.7	3.7	8.0	5.5	4.9	3.1
	4	4.2	2.8	4.4	4.4	3.7	3.9	522	8.5	8.5	8.8	7.5	7.4	5.8	6.0	12.3	5.7	5.9	5.8
+ K (mg/l)	1	1.4	1.4	1.7	1.7	1.7	1.7	10.0	1.8	2.2	1.8	2.1	1.6	-	-	1.7	1.8	2.2	1.6
	2	1.8	1.9	2.1	2.1	1.8	1.8	10.5	2.9	2.9	3.0	1.9	1.9	1.8	1.8	2.3	2.4	2.3	2.3
	3	1.3	2.2	2.2	1.9	1.3	1.7	18.8	1.7	2.1	1.8	2.1	1.8	2.1	2.4	1.4	1.6	1.7	1.5
	4	1.4	0.9	1.3	1.2	1.4	1.1	12.3	1.3	1.3	1.3	1.4	1.2	1.2	1.2	1.9	1.1	1.6	1.2
Total Cond. (µmho/cm)	1	280	281	268	270	257	262	2460	283	282	278	348	342	-	-	273	268	425	262
	2	303	302	269	262	261	260	2520	272	276	269	276	278	269	270	295	269	402	261
	3	282	218	197	190	206	168	2600	182	182	182	187	182	147	148	302	177	420	171
	4	257	179	188	188	161	160	2450	187	187	188	187	187	166	167	422	165	368	175

1/ Monitoring Sites: 1 = Milltown Dam, 2 = Council Grove, 3 = Harper's Bridge, 4S = Champion Side Channel, 4M = Champion Main Channel, 5 = Bud King's, 6 = Ninemile, 7 = Cyr, 8 = Superior

2/ 3/ Sample Date: 1 = December 16-20, 1985; 2 = January 21-24, 1986; 3 = March 10-12, 1986; 4 = April 8-17, 1986

Table 22. Semivolatile (phthalate ester and resin acids) analyses of water samples collected at eight monitoring stations on the Clark Fork River on April 17, 1986.

Semivolatile Compound	Monitoring Site: Milltown Dam I/ I	Milltown Dam S	Harper's Bridge I	Harper's Bridge S	Champion S.C. I	Champion S.C. S	Cyr I	Cyr S
Bis (2-ethylhexyl) phthalate (µg/l)	u*	u	u	2.5	573.0	b**	3.3	u
Benzyl butyl phthalate (µg/l)	u	u	u	u	14.2	b	u	u
Di-n-butyl phthalate (µg/l)	u	u	u	u	17.7	b	u	2.8
Diethyl phthalate (µg/l)	u	u	u	2.1	8.7	b	u	u
Unknown phthalate 1319 (µg/l)	u	u	u	u	146.1	b	u	u
" " 1367 (µg/l)	u	u	u	u	86.9	b	u	u
" " 1373 (µg/l)	u	u	u	u	29.1	b	u	u
" " 1403 (µg/l)	u	u	u	u	177.3	b	u	u
" " 1459 (µg/l)	u	u	u	u	55.9	b	u	u
" " 1504 (µg/l)	u	u	u	u	104.1	b	u	u
Phenanthrene (µg/l)	u	u	u	u	2.2	b	u	u
9.10 Anthracenedione (µg/l)	u	u	u	u	29.6	b	u	u

1/ Water Sample Source: I = Intergravel, S = Surface

* u = compound not detected (concentration below minimum detection limit)

** b = sample bottle broken in shipment

Chronic and acute toxicity criteria were exceeded at Champion and chronic criteria were exceeded at Cyr in intergravel water samples. The total concentration of phthalate esters in the intergravel at Champion was 1213 µg/l, indicating groundwater entering the Clark Fork River through seepage from the pulp mill's wastewater storage ponds is heavily contaminated with phthalate esters. Since phthalate esters were not detected in intergravel water samples collected at two monitoring sites located upstream from the pulp mill, it appears likely that phthalate ester found in the intergravel at Cyr is attributable to groundwater seepage from the pulp mill. Bis (2-ethylhexyl) phthalate (DEHP) was found in the intergravel at concentrations of 573.0 µg/l at Champion and 3.3 µg/l at Cyr. DEHP is commonly used as a plasticizer, an additive that gives rigid plastic flexibility (MDHES 1985).

Mayer et al. (1979) concluded the chronic phthalate ester criterion of 3 µg/l was not adequate to protect aquatic life. They recommended the criterion be reduced to 0.3 µg/l for bis (2-ethylhexyl) phthalate. In addition IJC (1976) recommends the following: "The concentrations of di-n-butyl phthalate and bis (2-ethylhexyl) phthalate in water should not exceed 4.0 and 0.6 µg/l, respectively, for the protection of aquatic life. Other phthalic acid esters should not exceed the recommended quantification limit of 0.2 µg/l in waters for the protection of aquatic life." These criteria were exceeded in the intergravel water at Champion, in the intergravel and surface water at Cyr and in the surface water at Harper's Bridge.

Mehrle and Mayer (1976) reported that bis (2-ethylhexyl) phthalate (DEHP) concentrations of 14 µg/l and greater caused mortality in sac fry of rainbow trout and altered backbone composition in the fry exposed for 90 days after hatch (Mayer et al. 1977). The no effect concentration of DEHP for sac fry mortality and bone development was 5 µg/l. Backbone composition, as measured by collagen concentration, was also altered in adult brook trout exposed to 3.7 µg/l of DEHP (Mayer et al. 1977).

Based on the above findings it appears likely that 100 percent mortality of brown trout eggs would have occurred at the Champion monitoring site during the 1985-86 incubation period due to high concentrations of phthalate esters in the intergravel environment. Egg survival and embryo development may have been impaired by phthalate esters in the intergravel environment at Cyr.

The presence of phthalate esters in the Clark Fork at concentrations exceeding chronic and acute toxicity criteria is disturbing. Additional monitoring should be conducted during the 1986-87 brown trout egg incubation period to provide a better understanding of this potentially serious problem.

Hydrogen sulfide (H_2S) is a common constituent of kraft mill effluents. It is also toxic at low levels to aquatic life. Its concentration depends on temperature and pH and can be calculated if the concentration of total dissolved sulfides is known (MDHES 1985).

Intergravel water samples for determining the possible presence and concentration of hydrogen sulfide were collected on April 14-15, 1986, near the end of the brown trout egg incubation period at Milltown Dam, Harper's Bridge, Champion (side channel) and Cyr. Total sulfide was below the laboratory detection limit of 0.2 mg/l as S at all stations, indicating that little, if any, hydrogen sulfide was present in the intergravel environment at the monitoring sites on these dates. However, hydrogen sulfide was detected by smell in the intergravel water sample collected at the Champion side channel. Hydrogen sulfide can be detected by smell at levels below the laboratory detection limit.

It appears unlikely that hydrogen sulfide detected by smell at the Champion station was present at a concentration high enough to adversely affect trout egg survival or embryo development. However, since hydrogen sulfide was monitored on only one occasion during the 1985-86 egg incubation period, additional monitoring should probably be conducted during the 1986-87 brown trout egg incubation period.

Trout Spawning and Recruitment Surveys

Visual surveys have been made in the Milltown Dam, Missoula, Huson and Superior study sections (Figure 1) during the rainbow and brown trout spawning periods in an attempt to locate trout redds. To date, redds have been located only in the Milltown Dam and Missoula sections. Since relatively little time has been spent on the visual surveys, additional observations need to be made in the Huson and Superior sections to evaluate the extent of trout spawning.

The search for trout redds in the Clark Fork River is hindered during both rainbow and brown trout spawning periods by poor visibility in deep water areas where spawning could occur. Visibility is sometimes precluded even in shallow water during the rainbow trout spawning period due to highly turbid spring runoff conditions. For this reason, use of the Clark Fork River for trout spawning will also be evaluated by electrofishing during the spawning periods in an attempt to locate concentrations of mature fish in spawning condition. Findings will be presented in future reports.

Electrofishing and "Idaho weir" fish trapping surveys indicate considerable numbers of rainbow, brown and westslope cutthroat trout migrate from the Clark Fork River into tributaries to spawn (Berg 1986). Significant trout fry outmigrations from several tributaries, monitored with fry traps, indicated tributaries provide considerable recruitment of juvenile trout to the Clark Fork River (Table 23).

Table 23. Trout fry outmigration rates monitored in five tributaries of the Clark Fork River during 1985 (Berg 1986).

Stream	Total Trap Nights	Rainbow Trout		W.S. Cutthroat Trout		Brown Trout		Bull Trout	
		Total Number Captured	Average Catch/ Trap Night	Total Number Captured	Average Catch/ Trap Night	Total Number Captured	Average Catch/ Trap Night	Total Number Captured	Average Catch/ Trap Night
Fish Cr	57	626	11.00	25	0.44	3	0.05	1	0.02
Ninemile Cr	46	493	10.72	0	0.00	14	0.30	0	0.00
Petty Cr	49	346	7.06	7	0.14	0	0.00	0	0.00
Rattlesnake Cr	31	65	2.10	1	0.03	1	0.03	0	0.00
Sixmile Cr	5	4	0.80	0	0.00	0	0.00	0	0.00

TROUT POPULATION CHARACTERISTICS

Methods

A boom-suspended electrofishing system was used to sample adult trout populations in four study sections on the main stem of the Clark Fork River. The electrofishing system was adapted from Novotny and Priegel (1974) and is described by Berg (1981). The electrofishing apparatus were mounted on a 4.5 m (14.6 foot) aluminum drift boat powered by a 9.9 horsepower outboard motor and a 6.1 m (20 foot) aluminum jet boat powered by a 215 horsepower inboard motor.

A mobile electrofishing system was used to sample juvenile and forage fish along shoreline areas of the Clark Fork River. This system is described by Berg (1986).

Fish captured by electrofishing were measured to the nearest mm in total length and weighted to the nearest 10 g. Sex and spawning condition (gravid, ripe or spawned) were recorded for fish captured during their spawning season. Several thousand catchable game fish were makred with individually numbered Floy T-tags to evaluate growth rate, movement and angler harvest. All fish were released near the capture site.

Population estimates were made using the Peterson mark/recapture formula as modified by Chapman (1951):

$$N = \frac{(M + 1)\ (C + 1)}{(R + 1)} - 1$$

where: N = population estimate
M = the number of marked fish
C = the number of fish in the recapture sample
R = the number of marked fish in the recapture sample (C)

Multiple marking and recapture runs were often needed to collect an adequate sample size. A partial fin clip or fin punch was used to mark the fish. A minimum of two weeks was allowed before recapture runs were made. Additional methods used for population and standing crop estimates are described by Vincent (1971 and 1974).

Scales were collected from some fish for age determination. The scale samples were imprinted on acetate, and the imprints were projected at 44 X magnification on a Norwest nmi 90 microfiche reader. Annuli were identified and ages assigned following procedures described by Jearld (1983) and Tesch (1971).

Results

Trout populations have been estimated by electrofishing and mark/recapture procedures in four study sections on the Clark Fork River. The study sections are located in the vicinities of Milltown Dam, Missoula, Huson and Superior (Table 24). Estimates in the four study sections indicate that the river supports from 175 to 402 catchable rainbow trout per mile (Table 25). Rainbow comprised more than 90 percent of the catchable trout population in all of the study sections. Catchable brown, westslope cutthroat and bull trout were present in the river, but their numbers were usually too low to estimate. In September, 1986, estimates of 16 catchable brown and 22 catchable westslope cutthroat trout per mile were obtained in the Missoula study section.

This density of catchable trout is less than expected for comparable trout streams the size of the Clark Fork. While the Clark Fork River supports an average of two to four hundred catchable trout per mile, other large trout rivers in Montana often support two to three thousand or more catchable trout per mile (Berg 1984).

Major tributaries to the Clark Fork River support larger populations of catchable trout than the main stem of the river. The mean number of catchable rainbow trout per mile in the Blackfoot River over a three-year period from 1983 to 1985 was 445 percent larger than the mean number of catchable rainbow per mile in the Clark Fork River during a three-year period from 1984 to 1986 (Tables 25 and 26). The comparison of the Blackfoot River with the Clark Fork is very appropriate since both rivers have similar physical habitat characteristics. Higher water quality in the Blackfoot River appears to be the major difference between the two rivers.

Trout population estimates presently can not be used to differentiate the affects the Missoula sewage treatment plant, the flushing of sediments from Milltown Dam or pulp mill effluent discharges on the sport fishery. However, the estimates do indicate that trout populations are depressed in the Clark Fork River from Milltown Dam to Superior despite the inflow of major tributaries with relatively high water quality. Findings from studies conducted to date suggest that if water quality is improved in the Clark Fork River, it should be capable of supporting larger populations of catchable trout.

Scales were collected from trout during population estimates to determine growth rates and age structure of the trout populations. Preliminary findings indicate growth rates of trout in the Clark Fork are relatively high when compared to trout streams of similar size. This indicates that food supply is probably not a limiting factor for trout populations in the Clark Fork River. Furthermore, it suggests that the Clark Fork River may be "under seeded" and that recruitment may be a limiting factor.

Table 24. Location, length and river mile index boundaries of fish population study sections on the Clark Fork River.

Section Name	Description of Location	Section Length (mi)	River Mile Index Boundaries
Milltown	Milltown Dam to 2.8 miles upstream from confluence of Rattlesnake Cr.	3.4	364.4 to 361.0
Missoula	Confluence of Bitterroot R. to 0.5 mile upstream from Harper Bridge	8.6	350.5 to 341.9
Huson	Confluence of Sixmile Cr. to 4.0 miles upstream from confluence of Petty Cr.	4.5	328.2 to 323.7
Superior	Confluence of Cedar Cr. to confluence of Dry Cr.	6.3	286.6 to 280.3

Table 25. Trout population estimates in four study sections of the Clark Fork River.

Study Section	Date of Estimate	Fish Species	Section Length(mi)	Catchable 1/ Trout/Section	Catchable 1/ Trout/Mile
Missoula	Sept. 1984	Rainbow	8.6	1506	175
Missoula	June 1985	Rainbow	8.6	1804	210
Milltown	June 1985	Rainbow	3.6	1035	288
Superior	July 1985	Rainbow	6.3	1382	219
Huson	Sept. 1985	Rainbow	4.5	1749	389
Missoula	Sept. 1986	Rainbow	8.6	3461	402
		Brown	8.6	137	16
	W.S.	Cutthroat	8.6	187	22
Huson	Sept. 1986	Rainbow	4.5	1504	334
				All Sections-Rainbow Mean($\bar{X}$)	288

1/ Catchable trout 7-inches total length and larger.

Table 26. Trout population estimates in the Johnsrud section of the Blackfoot River, approximately 13 miles upstream from Bonner.

Date of Estimate	Fish Species	Section Length (mi)	Catchable Trout/Section 1/	Catchable Trout/Mile 1/
June 1985	Rainbow	3.6	5,225	1,451
June 1984	Rainbow	3.6	3,186	885
June 1983	Rainbow	3.6	5,445	1,512
		Mean ($\bar{X}$)	4,618	1,282

1/ Catchable trout 7-inches total length and larger.

Limited electrofishing surveys indicated young-of-the-year trout were relatively scarce in the Clark Fork River during late summer, 1985 (Table 27). In the Missouri River below Holter Dam, a stream comparable in size to the Clark Fork below Milltown Dam, young-of-the-year trout were at least ten times more abundant than in the Clark Fork (Berg 1983).

A saturation plant of 10,000 hatchery reared young-of-the-year brown trout was made in the Huson section on June 23, 1986, to evaluate the possibility that recruitment is a limiting factor for trout populations in the Clark Fork River. Spawn were taken from a wild stock of brown trout at Harrison Lake, Montana, and the eggs were fertilized and incubated in the hatchery. The brown trout were reared in the hatchery until they were 2 to 4 inches in total length before being planted in the Huson section. Electrofishing surveys and population estimates will be continued in the Huson section to determine whether these fish eventually recruit into the adult population.

Physical characteristics of trout habitat will be evaluated in the Milltown Dam, Missoula, Huson and Superior study sections in 1987 in an attempt to determine whether the amount of suitable physical habitat constitutes a limiting factor for trout populations. Factors such as stream gradient, channel development, shoreline and instream cover, amount of spawning gravels and water temperature will be measured to aid in evaluating differences in habitat characteristics between study sections and to continue to more accurately evaluate whether trout population characteristics are affected by pulp mill effluent discharge.

Potential impacts of year round discharge of pulp mill effluents on trout populations and the sport fishery of the middle Clark Fork River represent a legitimate public concern. Additional time is needed to adequately assess potential impacts of year round discharge on trout reproductive success, trout population characteristics, trout food supply and sport fishing success rates.

Table 27. Average size and relative abundance of young-of-the-year trout sampled by electrofishing in four study sections of the Clark Fork River during late summer 1985.

Study Section	Date	Trout Species	Average Length (mm)	Juvenile Trout Electrofished/Hour
Milltown	8/26/85	Rainbow	57	7.1
		Brown	90	10.7
Missoula (side channel)	8/28/85	Rainbow	76	1.7
		Brown	94	10.0
Missoula (main river)	8/28/85	Rainbow	63	1.4
		Brown	-	0.0
Huson	8/30 & 9/4/85	Rainbow	60	3.6
		Brown	77	0.3
Superior	9/5/85	Rainbow	58	14.6
		Brown	81	1.1

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